PROCEEDINGS

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# SPINAL MUSCLE ACTIVITY DURING DIFFERENT RUGBY SCRUM ENGAGEMENT PROCEDURES

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Biomechanical studies of rugby union scrummaging have focussed on kinetic and kinematic analyses, whilst muscle activation strategies employed by front row players during scrummaging are still unknown. The aim of this study was to investigate the activity of the sternocleidomastoid, upper trapezius and erector spinae muscles during machine and live scrums. Nine male front-row forwards scrummaged individually against a scrum machine under 'crouch-touch-set' and 'crouch-bind-set' conditions, and against a two-player opposition in a simulated live condition. Results suggest that the pre-bind technique, may effectively prepare the cervical spine by stiffening joints before the impact phase. Additionally, machine scrummaging does not replicate the muscular demands of live scrummaging for the erector spinae.

**KEY WORDS:** biomechanics, scrummaging technique, sport injury, cervical spine, EMG.

**INTRODUCTION:** Rugby scrummaging places intense biomechanical demands on players, particularly those playing in the front row. Due to its physical nature, the scrum is associated with approximately 6 to 8% of all rugby injuries (Trewartha et al., 2014), 40% of catastrophic injuries (Brown et al., 2013), and may lead to chronic degenerative spinal injuries. Machine and live scrummaging biomechanics have been described in terms of the forces generated and motions observed (Cazzola et al., 2014; Preatoni et al., 2014). From these investigations, the scrum has undergone a number of rule changes, most recently from a 'crouch-touch-set' (CTS, in 2012/2013) to a 'crouch-bind-set' (CBS, in 2013/2014) procedure, in an attempt to improve safety by de-emphasising the initial impact of the scrum engagement (Cazzola et al., 2014; Preatoni et al., 2014). Currently, no study has investigated the effects of rule and technique changes on spinal muscle activity. The analysis of neuromuscular activation patterns under different engagement conditions is fundamental to elucidate the strategies employed by front row players as they prepare their bodies for the engagement and pushing actions. The aim of this study was to determine the activity of the bilateral upper trapezius, sternocleidomastoid and erector spinae muscles under three scrummaging conditions; two machine scrummaging conditions, the 'crouch-bind-set' and 'crouch-touch-set' and a single live scrummaging condition were investigated

**METHODS:**In a repeated measures design, a group of rugby union front row forwards performed multiple trials in three different simulated scrummage conditions (within-group factor) and throughout the phases of scrummaging (within-group factor) to assess and compare spinal muscle activity (dependent variable). Nine male rugby union players (age 20.3 ± 1.3 year, height 1.80 ± 0.10 m, weight 102.36 ± 15 kg), of at least University 1st XV standard with a minimum of 3 years playing experience in the front row and no history of spinal injuries in the 12 months prior to testing, participated in the study.
Data collection: For electromyography (EMG) collection, six wireless electrodes (DelsysTrigno, DelsysInc), sampling at 2000 Hz, were attached to: the sternocleidomastoid, and upper trapezius accordingly to Sharp et al. (2014).
Two isometric maximal voluntary contractions (MVC) trials were performed for each muscle of interest. The three different engagement techniques: crouch-touch-set (CTS), crouch-bind-set (CBS) and live 1-versus-2 scrummaging (Live) were presented in a blocked random order. The machine scrummaging conditions involved a single participant engaging with an instrumented scrum machine using the CTS and CBS variants followed by a sustained push

(Preatoni et al., 2012). The live condition involved a single participant passively engaging, for safety reasons, with two other participants prior to the sustained push. A bespoke control and acquisition system was programmed to synchronously trigger the acquisition hardware, collect and store the forces measured through the instrumented scrum machine, and playback pre-recorded cues given by the referee (Preatoni et al., 2013). Muscle activity was measured for 10 s from 1 s prior to the "crouch" call.

*Data Processing:*Raw electromyograms were filtered by applying a bi-directional second-order Butterworth low pass and high pass filter between 20-200 Hz. The data were then rectified and smoothed using a moving average over 50 ms windows. EMG signals were normalised to the MVCs. Average muscle activity (average rectified EMG amplitude) during scrum trials was calculated over three phases of each scrum: the pre-engagement, the engagement and the sustained push phases.

*Statistics:* Separate one-way repeated measure analysis of variance (ANOVA) (with scrummage conditions as the within-group factor) and Bonferroni post-hoc analysis were applied (SPSS software, IBM Corp, USA) to determine if there were any differences ($p < 0.05$) in muscles' activation across scrummage conditions during the sustained push phase (CBS vs CTS vs Live). A paired t-test was performed to determine the differences in muscle activation in the pre-engagement phase (CBS vs CTS), and the engagement phase (CBS vs CTS), as Live engagement included only the sustained push phase. Further one-way repeated measure ANOVAs (with scrum phases as the within-group factor) were used to test possible changes in muscles activation across the different phases of the scrum for the CTS and CBS machine trials, followed by Bonferroni post-hoc comparisons ($p < 0.05$). Pairwise effect sizes calculated using Cohen's $d_z$ statistic ($|d_z|$ >1 large effects; $|d_z| > 0.8$ moderate effects; $|d_z| > 0.5$ small effects) were also calculated.

**RESULTS:** *Comparing Conditions*: In the pre-engagement phase, all the measured muscles in both machine conditions were activated in excess of 25% MVC (Figure 1). The activity of the sternocleidomastoid and upper trapezius was significantly higher ($p < 0.01$) in the CBS condition than the CTS condition. The activity of the erector spinae tended to be more activated (large effect size, $d > 0.8$), although not significantly ($p > 0.05$), in the CTS condition during pre-engagement than the CBS condition. During the engagement phase all the measured muscles were more active in the CBS than CTS condition. The activity of the upper trapezius and sternocleidomastoid were significantly higher ($p < 0.05$ – paired t-test), showing an average increase of 20% ± 12% and 22% ± 20% respectively (Figure 1).

During the sustained push phase the activity of the muscles across all three conditions (CBS, CTS and Live) could be compared. The activity of the erector spinae during the sustained push phase was significantly higher in live scrummaging than in either of the CBS (56% ± 26% greater) or CTS (62% ± 18% greater) conditions ($p < 0.01$), with the erector spinae activity approximately 56% ± 26% lower (CBS vs Live) and 62% ± 18% lower (CTS vs Live). The activity of the upper trapezius tended to be lower in the CTS than in the CBS and Live conditions, whereas the activity of the sternocleidomastoid was similar across conditions.

*Comparing across phases*: The activity of the sternocleidomastoid and erector spinae showed a decreasing trend ($p < 0.05$) moving from pre-engagement through engagement to the sustained push in both the CBS and CTS conditions (Figure 1). The activity of the sternocleidomastoid was significantly higher during the pre-engagement and engagement phase than sustained push in CBS ($p < 0.05$), and in CTS pre-engagement tended to be higher than sustained push ($p = 0.059$). The activity of the erector spinae during both CBS and CTS conditions was significantly higher during both the pre-engagement phase ($p < 0.05$) and engagement phase ($p < 0.05$) when compared with the sustained push (Figure 1). There was a significant pattern of decreasing activation from i) pre-engagement to engagement and from ii) engagement to sustained push.

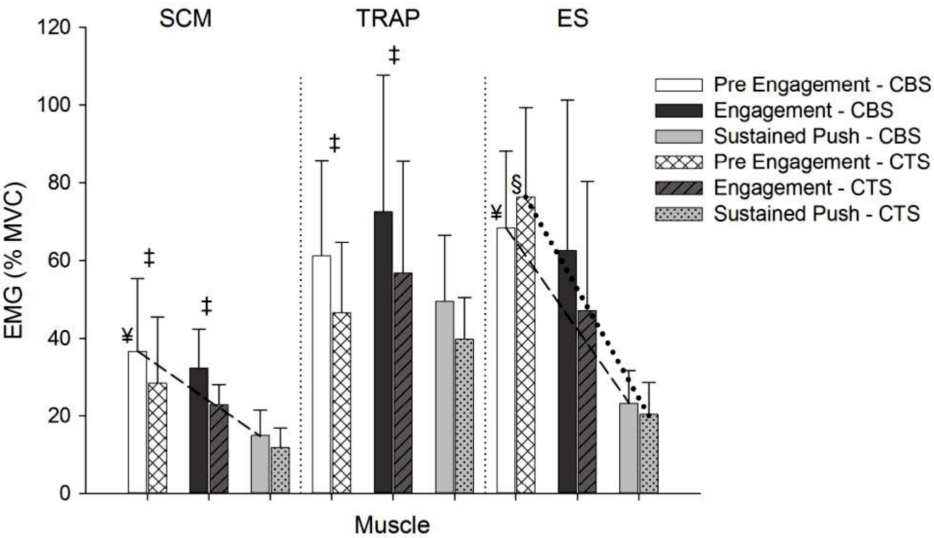


**Figure 1: Normalised values (% MVC) of muscles activation (mean and SD) of sternocleidomastoid (SCM), upper trapezius (TRAP) and erector spinae (ES) during CBS and CTS engagements. Muscles activation during CBS and CTS engagements are shown throughout the three scrum phases: pre-engagement, engagement and sustained push. Live engagement is not included because in that condition EMG measures were carried out only during sustained push phase. The dashed and dotted lines show the muscles activation trend in respectively CTS and CBS, and are representative of the differences (ANOVA) between i) pre-engagement and sustained push and ii) engagement and sustained push. ‡ = significant difference between CBS and CTS ($p<0.05$ – paired t-test); ¥=significant difference between both i) pre-engagement and sustained push, and ii) engagement and sustained push in CBS ($p<0.05$ - ANOVA);§= significant difference between both i) pre-engagement and sustained push, and ii) engagement and sustained push in CTS ($p<0.05$ - ANOVA).**

**DISCUSSION:** The aim of this study was to gain more insight into the activity of sternocleidomastoid, upper trapezius and erector spinae muscles during machine (CBS and CTS) and live scrummaging. Compared with the machine conditions, the live condition resulted in significantly higher activation of erector spinae during the sustained push phase. Also, the activity of sternocleidomastoid, upper trapezius and erector spinae tended to be greater during the CBS condition than the CTS condition throughout the three phases of the scrum. Spinal muscle activity in both machine scrummaging conditions was characterised by a considerable pre-activation of all 6 muscles (>25% MVC) prior to engagement. This pre-activation can functionally lead to an increase in cervical and lumbar spine stiffness, which may better prepare the player's spinal structures for the high biomechanical loads placed upon the spine during engagement. A high level of muscle pre-activation may potentially mitigate the effect of loads on spinal posture and help maintain optimal neutral spine position (Brooks & Kemp, 2011). However, the stabilisation of the spine due to high-level of muscles activation may not be enough to limit cervical spine hyperflexion or buckling mechanisms (Dennison et al., 2012) during catastrophic injury, and further analyses are needed to elucidate the actual contribution that muscle activations can make in certain high-risk loading conditions.The activity of the spinal muscles was comparable between the conditions and the activity of sternocleidomastoid and upper trapezius was found, in the engagement phase, to be significantly greater in the CBS condition. This pre-bind posture may effect spinal muscle activation, where greater upper trapezius and sternocleidomastoid activation increase cervical spine stiffness and may better maintain cervical spine posture during the engagement. This indicates that a pre-bind procedure makes the upper spine more prepared for the scrum engagement.
The activation of the erector spinae was significantly higher throughout the sustained push phase of the live scrummaging condition than either of the machine scrummaging conditions.

Live scrummaging is an unstable dynamic condition when compared with machine scrummaging, therefore the forces applied to the opposition players are not equally matched in direction or magnitude, as they are during a scrum against the machine. These findings demonstrate that although machine and live scrummaging show comparable kinematic and kinetic characteristics, machine scrummaging does not accurately replicate live scrummaging in terms of muscle activation strategies required to maintain the sustained phase. Thus, it can be suggested that front row players should be required to train in live situations and not only against scrum machines. Therefore, a relative increase in live scrummaging practise may be beneficial for all front row players from the perspective of training appropriate and specific neuromuscular activation patterns. This may be particularly important under current rugby practice since the duration of the sustained phase has markedly increased under the CBS engagement procedure.

**CONCLUSION:** In conclusion, the activation of selected spinal muscles is greater in the CBS condition than the CTS condition, particularly in the pre-engagement phase. This indicates that the muscles of the cervical spine, in the CBS condition, are better prepared for the forces experienced during the scrum engagement than in the CTS condition as cervical spine stiffness is greater. Furthermore, this research provides evidence that the erector spinae is significantly more active during live scrummaging than machine scrummaging. This reinforces the requirement for individuals to practise and learn scrummage techniques in a live situation, rather than purely against a machine, as machine scrummaging does not replicate the demands of a live contest. Future research should build on the foundations of the current study, with the objectives of improving its ecological validity through trials on natural turf and in a more complete scrummaging scenario (a full front row or a complete pack) either against a scrum machine or in live conditions.

**REFERENCES:**

Brooks JHM, Kemp SPT. Injury-prevention priorities according to playing position in professional rugby union players. *British Journal of Sports Medicine*. 2011: 45: 765-775.

Brown JC, Lambert MI, Verhagen E, Readhead C, van Mechelen W, Viljoen W. The incidence of rugby-related catastrophic injuries (including cardiac events) in South Africa from 2008 to 2011: a cohort study.*BMJ open*. 2013: 3.

Cazzola D, Preatoni E, Stokes KA, England ME, Trewartha G. A modified prebind engagement process reduces biomechanical loading on front row players during scrummaging: a cross-sectional study of 11 elite teams.*British Journal of Sports Medicine*. 2014:49:541-546.

Dennison CR, Macri EM, Cripton PA. Mechanisms of cervical spine injury in rugby union: is it premature to abandon hyperflexion as the main mechanism underpinning injury?*British Journal of Sports Medicine*. 2012: 46: 545-549.

Preatoni E, Stokes KA, England ME, Trewartha G. Engagement techniques and playing level impact the biomechanical demands on rugby forwards during machine-based scrummaging.*British Journal of Sports Medicine*. 2014: 49: 520-528.

Trewartha G, Preatoni E, England ME, Stokes KA. Injury and biomechanical perspectives on the rugby scrum: a review of the literature. *British Journal of Sports Medicine*. 2014.

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